Technology Assessment Working Group

Interim briefing to TST

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Loren Lemmerman

The Team

- **James Duda**
- **Jeff Simmonds**
- **Amy Walton**
- **Walt Brooks**
- **Jim Bilbro**
- **Jim Gatlin**
- **Murray Hirschbein**
- **Brantley Hanks**
- **Tom Stanley**

Background

- **Charter:** **Develop a process to evaluate maturity of technologies embedded in a proposed or early phase project suitable for application by the project and by external review panels**
- **Approach:** **Solicit team from across NASA to advise.**
- **Locations: IPO, ARC, GSFC, MSFC, SSC, HQ, JPL,**

Interim Report Topics

- **Status**
  - **Proposed Assessment Process**
  - **Steps Remaining to be Defined**
- **Proposed Schedule for completion**
- **Issues for Discussion**

Scope (1)

- **Practical Approach**
  - **Builds on and Defines the Application of the Standard TRL Approach Already Familiar to NASA**
  - **Relies on Product Breakdown Structure of the Project**
  - **Applies to Any Major Gate in Project Lifecycle for Which There Remain Outstanding Technology Issues.**
  - **Examples:**
    - **Pre Phase A to Phase A**
    - **Phase A to Phase B**
    - **Phase B to Phase CD**
    - **ESSP Step 1 Proposals**
    - **ESSP Step 2 Proposals**

Scope (2)

- **Applies to Evaluation of Technologies Embedded in a Project, and Assessment of Attendant Impact of that Technology on Project .**
  - **Includes Both Hardware and Software Technologies**
  - **Should Be Used by Project Teams As a Tool for Understanding Their Own Project Risks**
  - **Should Be Used by Review Teams for Project Assessments**
- **Applies to Technology Developers Themselves**
  - **To Assist in Evaluating Readiness and to Help in Preparing Technology Development Proposals.**
  - **Proposal Reviewers Should Use This Evaluation As a Template to Assure That the Evaluation Was Done Thoughtfully.**

Scope (3)

- **Includes Assessment of Likely Cost and Schedule Required to Mature Chosen Technology Path**
- **Does Not Address Other Aspects of Project Risk, Eg What Overall Project Costs May Be Incurred As a Result of Schedule Slippage in Delivery of Technology.**

Three Uses of Process

- **Project internal**
  - **Systems engineer**
  - **Technologists**
  - **Above use tool to evaluate technology approach vs SOA fallbacks**
    - **Pro: internal,part of design process and trade studies**
    - **Con: does not benefit from independent review or expertise**
- **Independent Peer Review /SMO**
  - **Interviews of project team by outside experts**
    - **Could draw on other FFRDC, DoD experts**
  - **Data recorded in Excel tool**
    - **Pro: takes advantage of outside expertise; allows assessment of competing technologies; more open process; more in-depth analysis including competing technology options**
    - **Con: more costly, takes more time to do; tough to find qualified outside experts who are not competitors**

Three Uses of Process (cont'd)

- **Non-advocate Team of Experts "Employed by Review Panel/ SPO/ Customer" to Evaluate Proposed Approach**
  - **If Project Used TA Tool, Evaluation Board Would Judge Credibility of Answers**
  - **If Project Did Not Use Such a Tool, Evaluation Board applies TA Approach to Proposal to Perform as Much Assessment as possible**
    - **Pro: Potentially Most Thorough Scrub of Technology Readiness Without Biases**
    - **Con: Does not provide for Access to Alternate Implementations or Other Technological Approaches**
- **The Ideal Flow Is to Have All Three Levels of Review:**
  - **Project Internal**
  - **Project Peer Review**
  - **Outside Evaluation Board**

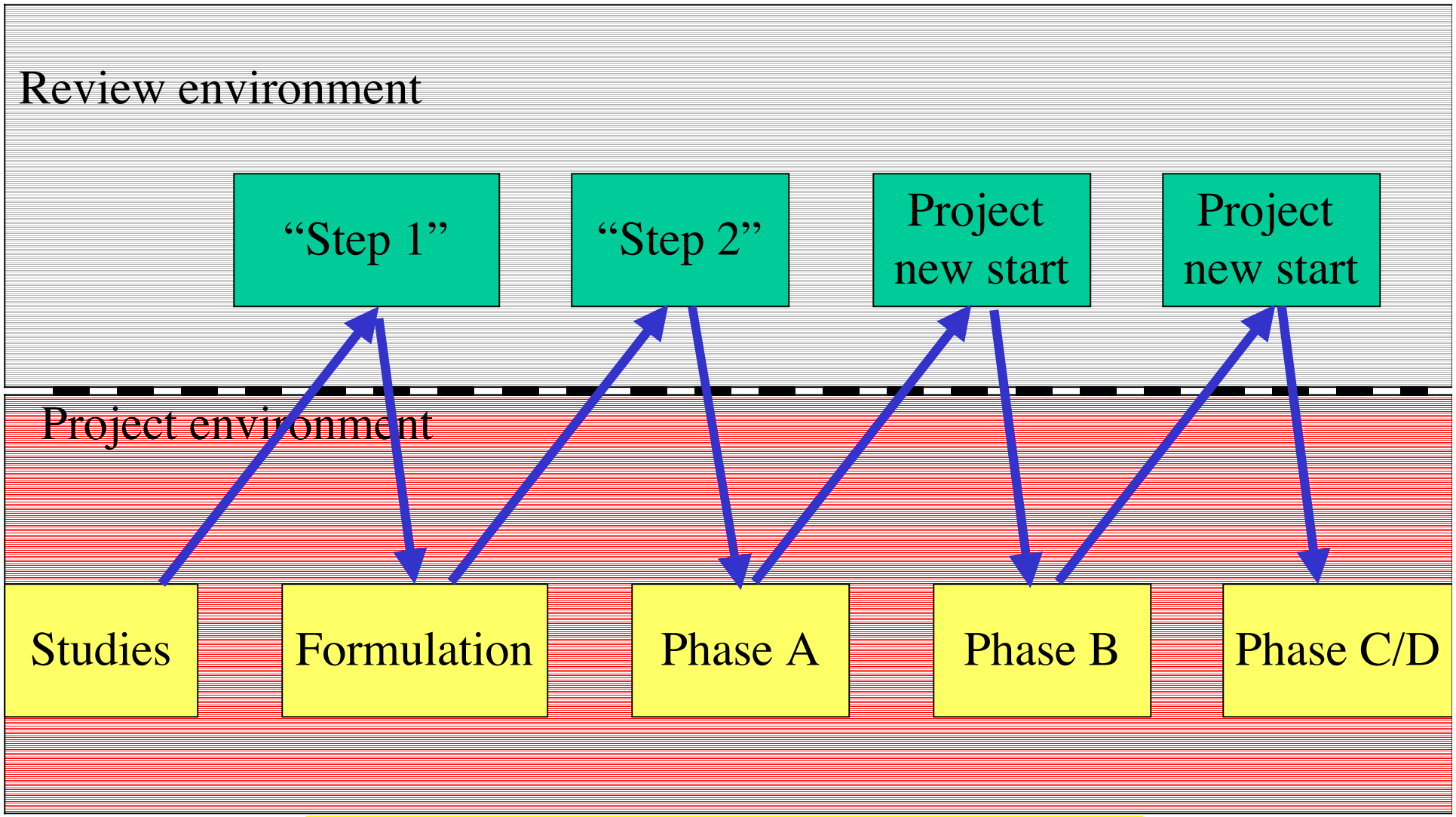
Application of TRL definitions to hardware

	TRL Graduation Requirements	
Level	**Definition**	**Evaluation Criteria**
TRL 1	***Basic principles observed and reported***	NTR Or Equivalent
TRL 2	***Technology concept and/or application formulated***	Data published documenting observed characteristics ; speculation on possible applications
TRL 3	***Analytical and/or experimental critical function proof-of-concept***	Data published with analytical studies to validate application concept and to predict performance in application
TRL 4	***Component and/or breadboard validation in laboratory environment***	Components of the future operational system defined; Critical components breadboarded and successfully demonstrated in the lab
TRL 5	***Component and/or breadboard validation in relevant environment***	Critical components upgraded to operate in a representative environment and successfully demonstrated in that environment
TRL 6	***Prototype demonstration in a relevant environment (ground or space)***	Components integrated into a prototype system performing essential function, operated in a representative environment and successfully demonstrated in that environment
TRL 7	***System prototype demonstration in a space environment***	Components integrated into a prototype system honoring form, fit and function, operated in a representative environment and successfully demonstrated in that environment
TRL 8	***Actual system "flight qualified" through(ground or space) demonstration***	Operating system flown in space, either as a demonstration on a science mission, or as an operational item in a science mission, or in a dedicated technology demonstration in space.
TRL 9	***Actual system "flight proven" through successful mission operations***	Accepted operational system

Application of TRL definitions to software

	TRL Graduation Requirements	
Level	**Definition**	**Evaluation Criteria**
TRL 1	***Basic principles observed and reported***	Mathematical formulations and basic properties of algorithms have been reported
TRL 2	***Technology concept and/or application formulated***	Experiments performed with synthetic data.
TRL 3	***Analytical and/or experimental critical function proof-of-concept***	Experiments performed with small representative data sets. Scientific feasibility fully demonstrated.
TRL 4	***Component and/or breadboard validation in laboratory environment***	Standalone prototype implementations completed. Experiments condeucted with full scale problems or data sets.
TRL 5	***Component and/or breadboard validation in relevant environment***	Prototype implementations conform to target environment/interfaces. Experimentsdoen with realistic problems. Simulated interfaces to existing systems.
TRL 6	***Prototype demonstration in a relevant environment (ground or space)***	Partially integrated with existing hardware/software systems. Limited documentation available. Engineering feasibility fully demonstrated.
TRL 7	***System prototype demonstration in a space environment***	System prototype demonstrated in high-fidelity environment (parallel or shadow mode operation) Well integrated with operational hardware/software systems. Most software bugs removed. Limited documentation available.
TRL 8	***Actual system "flight qualified" through(ground or space) demonstration***	Thoroughly debugged software. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. V&V completed.
TRL 9	***Actual system "flight proven" through successful mission operations***	Thoroughly debugged software readily repeatable. Fully integrated with operational hardware/software systems. All documentation completed. Successful operational experience.

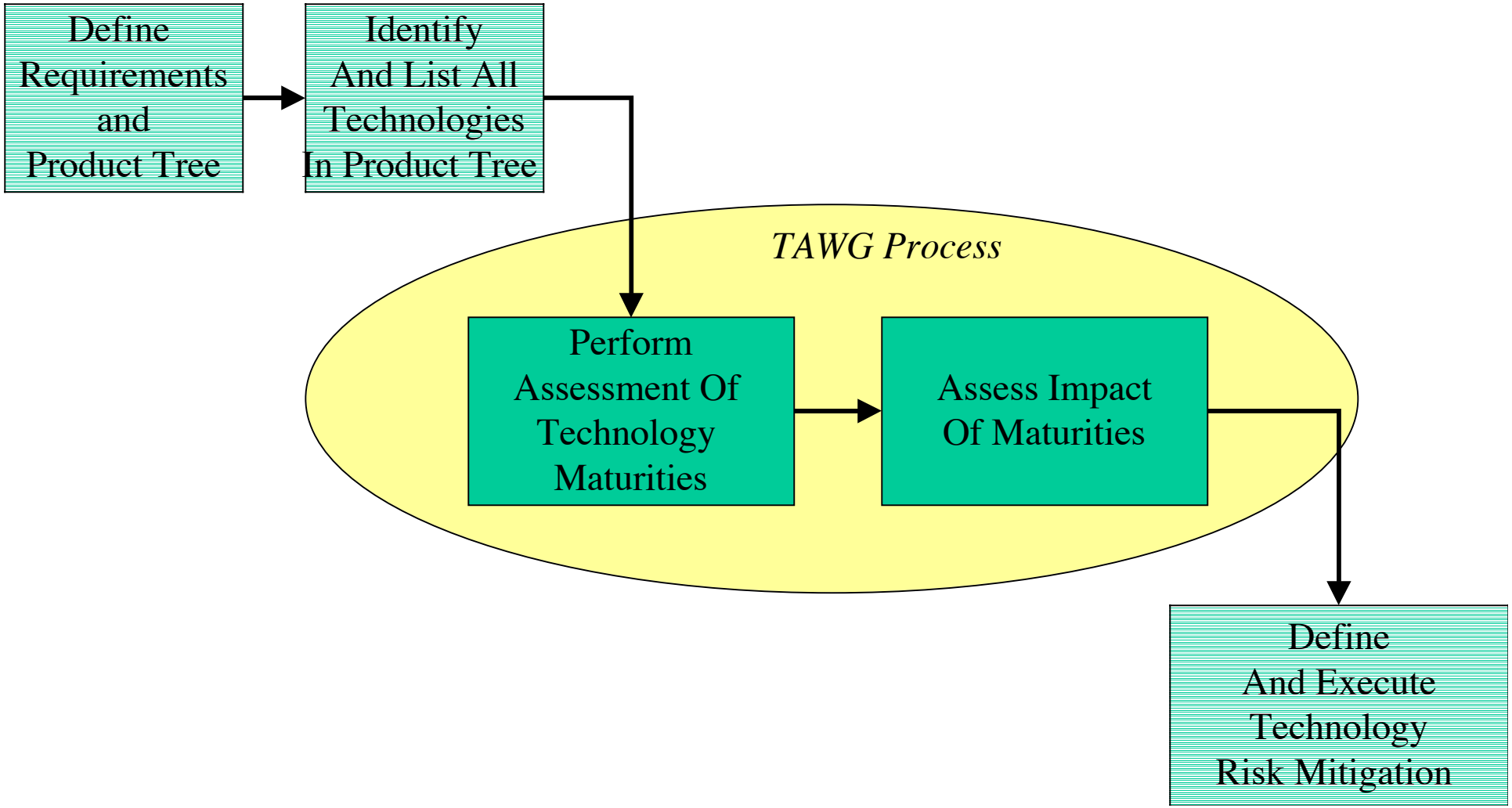
Application of Process throughout Lifecycle



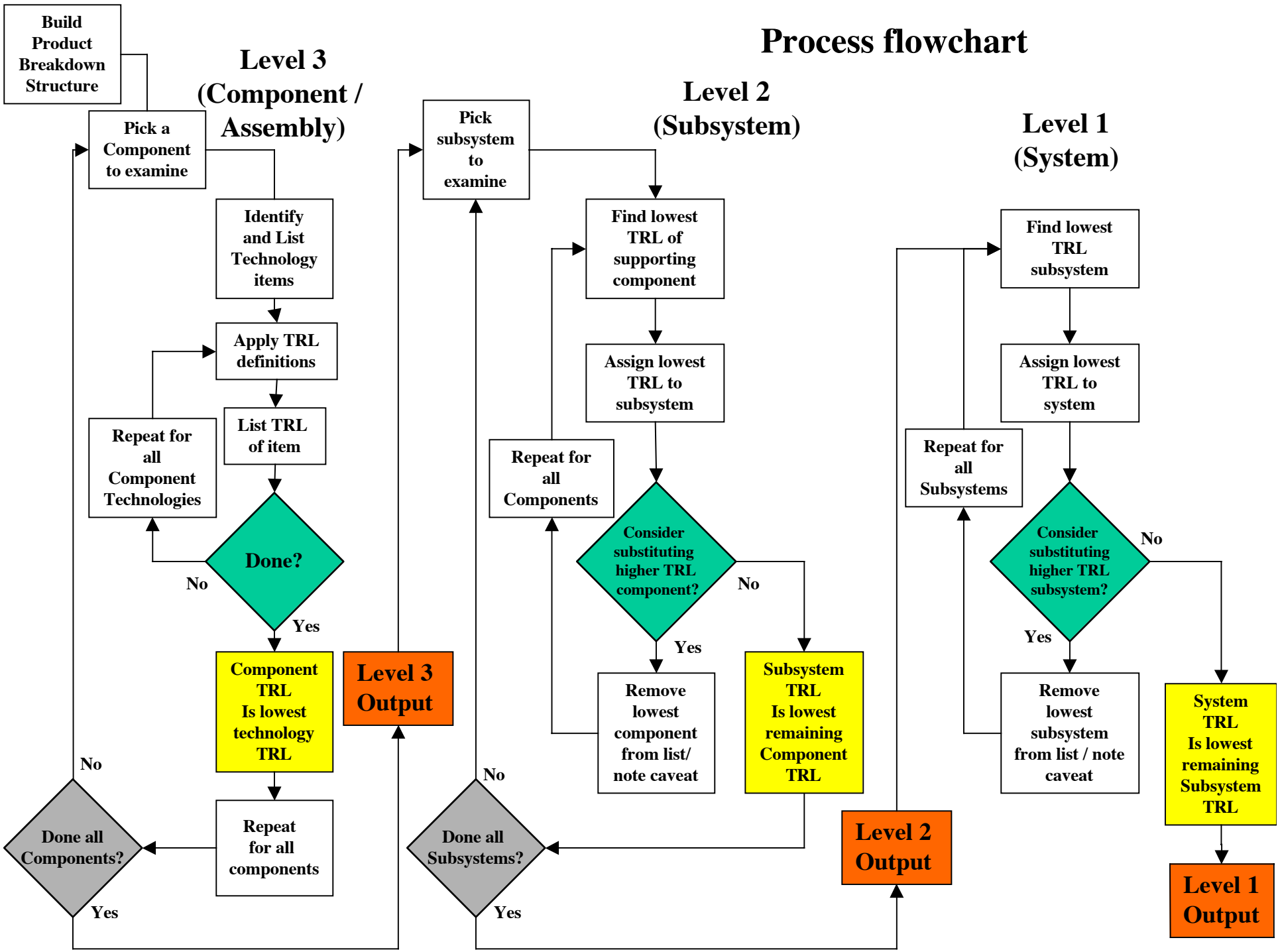
Common to all: Technology Assessment

Assessment Process

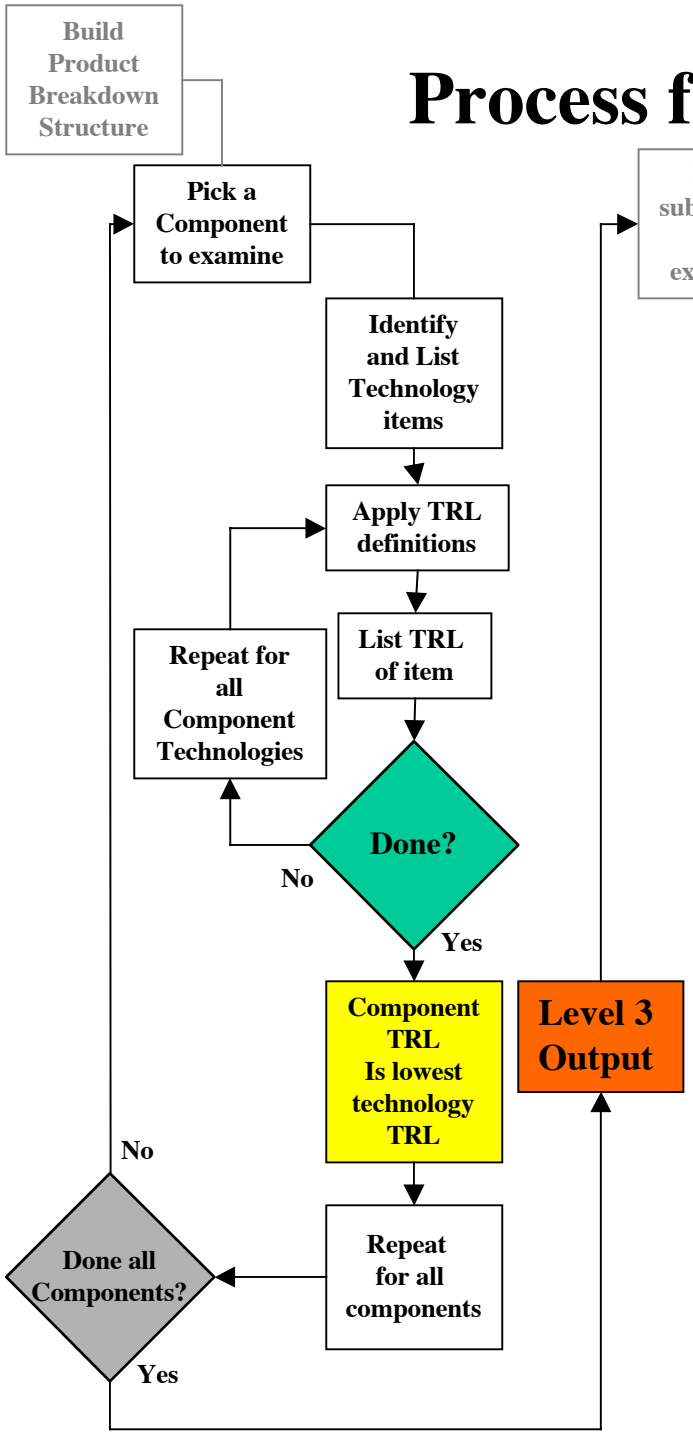
Top level process



Process flowchart



Process for Component Evaluation

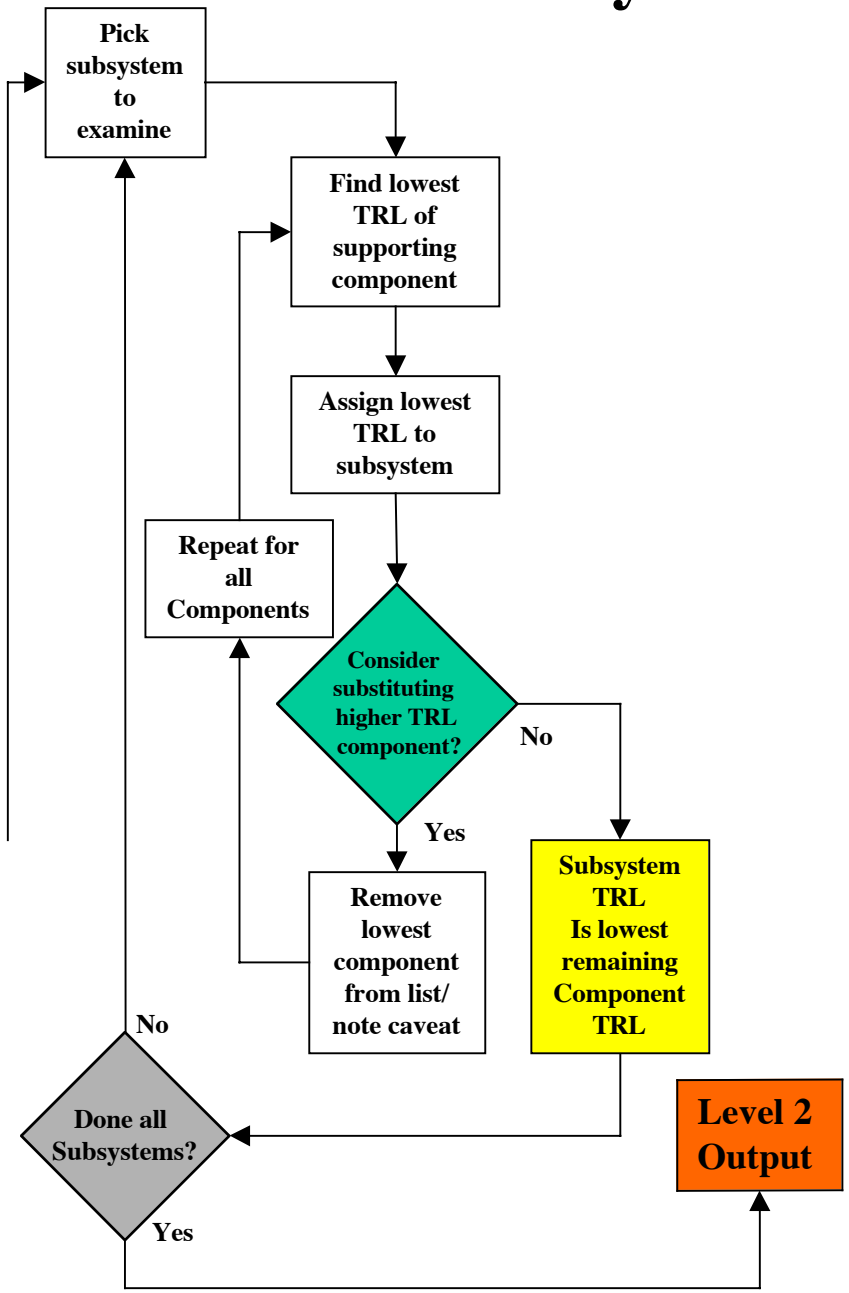


- For any given Component, there could be several technology items.
  - All technology items need to be assessed
  - Component TRL equals the lowest of the technology TRLs
- Level 3 output lists TRL levels by Component

Level 3 worksheet

Component identity	Technology Item for this component	current TRL	Rationale for TRL (i.e.,back up data, test results, etc.)
Conclusion: From this level 3 pass, system TRL is the lowest TRL listed			
Note: For each component, its TRL is the lowest TRL of any technology item			

Subsystem Level Assessment

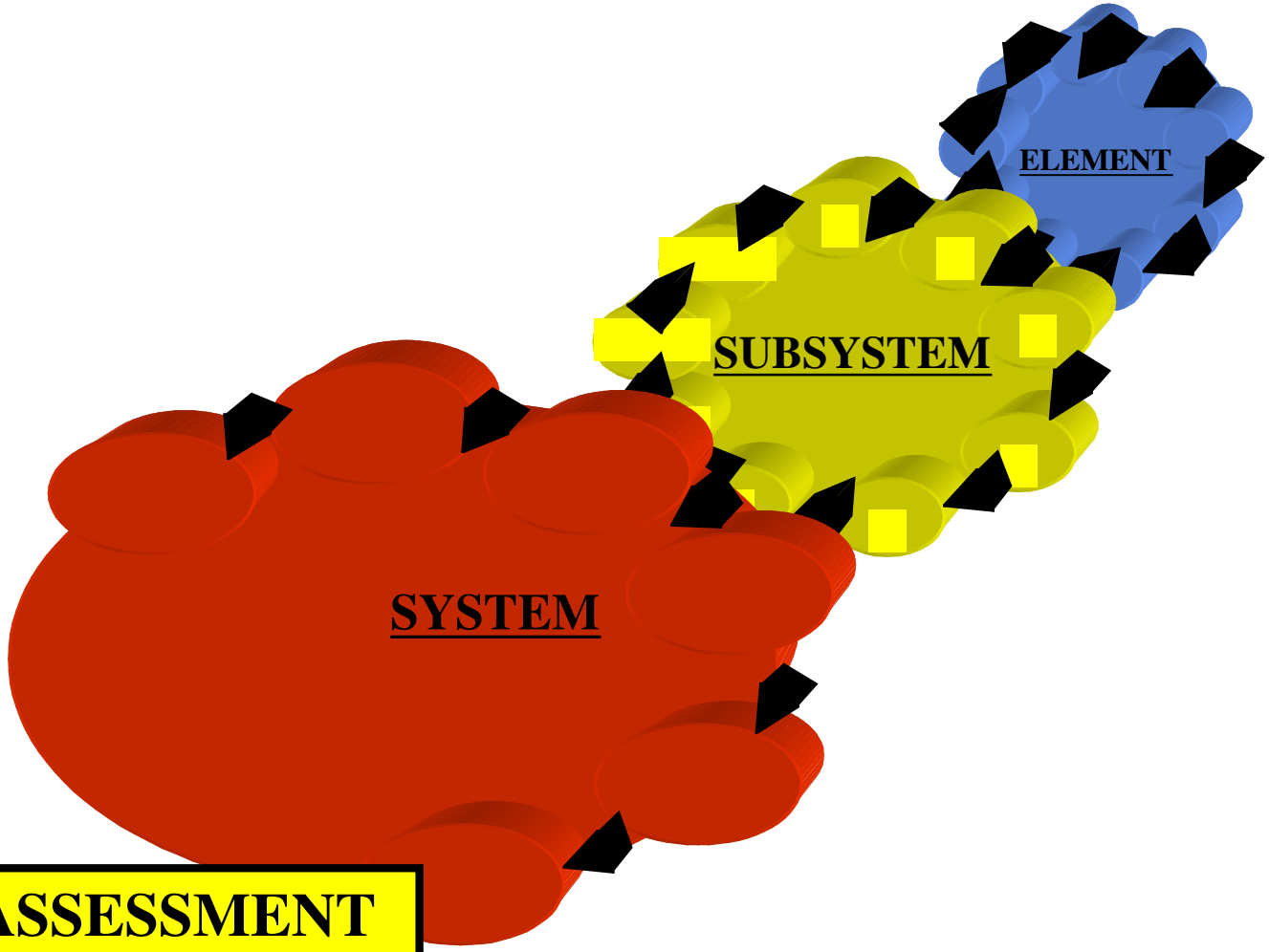


- Process for evaluating subsystem depends on Component Level Evaluations
- Fundamentally, Subsystem TRL equals the Lowest Component TRL…EXCEPT THAT
- Process explicitly suggests substituting less technologically advanced components to improve
  - Replacing lowest TRL component increases Subsystem TRL
  - Replacing ANY component requires listing performance impact of substitution
- Level 2 report lists TRL by subsystem, INCLUDING all potential substitutions AND impacts

Subsystem (Level 2) Worksheet

subsystem	subsystem TRL (from page 2)		identify substitute subsystem that has no technology component	Quantify Impact fo fallback to substitute
1	5	if we accept…		
	3	if we accept…		
	2	if no substitutes made		
2	4	if we accept…		
	3	if we accept…		
	2	if no substitutes made		
2a			Substitute subsystem 2a will be used since no option for subsystem 2 is acceptable to the project	
3..	6	if we accept…		
	5	if we accept…		
…n	6	if we accept…		
	5	if we accept…		
	4	if we accept…		
	2	if we accept…		
	1	if no substitutes made		
Recommendation				
build system with the following:				
1	5	if we accept…		
2	2a			
3	5	if we accept…		
…				
n	4	if we accept…		
Note: For the system, its TRL is the lowest TRL of any non-substituted subsystem				

Multiple Level Assessment



THE SAME ASSESSMENT PROCESS IS APPLICABLE AT ALL LEVELS

Summarizing system status

TRL Assessment

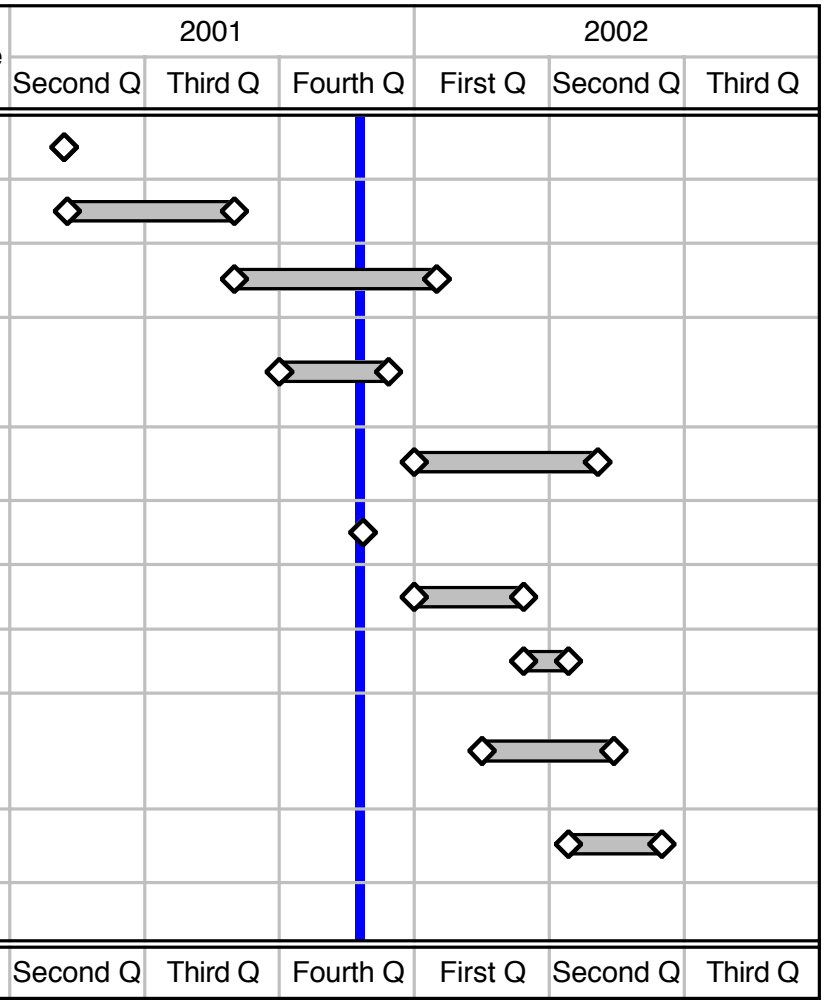
		Demonstration Units					Environment				Unit Description					
R	Red = Below TRL 3															
Y	Yellow = TRL 3,4 & 5															
G	Green = TRL 6 and above															
W	White = Unknown															
X	Exists															
		Concept	Breadboard	Brassboard	Developmental Model	Prototype	Flight Qualified	Laboratory Environment	Relevant Environment	Space Environment	Space/Launch Operation	Form	Fit	Function	Appropriate Scale	Integraton	Overall TRL
1.0 System																	
1.1 Subsystem X																	
1.1.1 Mechanical Components																	
1.1.2 Mechanical Systems																	
1.1.3 Electrical Components					X				X		X	X	X				
1.1.4 Electrical Systems																	
1.1.5 Control Systems																	
1.1.6 Thermal Systems							X				X	X					
1.1.7 Fluid Systems		X															
1.1.8 Optical Systems																	
1.1.9 Electro-optical Systems																	
1.1.10 Software Systems																	
1.1.11 Mechanisms	X																
1.2 Subsystem Y																	
1.2.1 Mechanical Components																	

Next Steps:

- **Estimate cost of practical application**
- **Address technology maturity impact**
  - **Objective is to assess the potential cost and schedule impacts associated with various 'technology options' associated with each trl level.**
  - **Begin with Jim Bilbro's 'degree of difficulty' chart**
- **Apply to Pilot Project(s)**
- **Develop tools to support assessment**

Project Gantt chart

Activity Name	Start Date	Finish Date
Receive Assignment	5/8/01	5/8/01
Form Team	5/10/01	9/1/01
Develop Assessment Concepts	9/1/01	1/15/02
Develop TRL Graduation Requirements	10/1/01	12/15/01
Develop Tools to Facilitate	1/1/02	5/4/02
Identify Pilot Projects	11/28/01	11/28/01
Apply to Pilot Projects	1/1/02	3/15/02
Modify Process	3/15/02	4/15/02
Develop Implementation Approach	2/15/02	5/15/02
Document with Final Report	4/15/02	6/15/02



Issues for Discussion

- **Prototype / pilot (at least 2 centers recommended)**
  - **ESSP**
  - **?**
  - **Resources for performing pilots**
- **How to populate teams**
  - **Mix of technologists and SE**
  - **ESTO if at all possible? How many reviews would need to be supported every year?**
- **Implementation approach**
  - **This is a tool for existing reviews / not a new review**
  - **Useful at all project gates**
  - **Centers / projects decide how to implement?**
- **Ownership and facilitation of process in long term**
  - **Future project leaders**
  - **Future reviewers**
  - **ESTO ownership?**